

There is something to be said both for and against the shading of rainfall maps to indicate heavy precipitation on mountain slopes where no actual measurements have been made.

That precipitation increases on mountain slopes up to about 4,000 feet elevation is generally admitted, but what the law of distribution is above that level has not been determined for the mountain regions of the far west. The quantity of rain that falls on a mountain slope is not solely a question of elevation. The angle of incidence that the mountain slope makes with the rain-bearing winds is of much more importance than the absolute elevation. The principle enunciated by Professor Jefferson, viz, that hill precipitation must tend to exceed that of neighboring lowlands, has little, if any, *practical application* in the construction of normal rainfall maps where small differences in elevation are concerned. Let us look for a moment at a few records of hill and valley precipitation, taken from the last published annual report of the New England Climate and Crop Service, viz, that for 1900, page 7. The highest point in Massachusetts at which rainfall observations were made in that year was Pittsfield, in the Berkshire Hills, elevation 1,038 feet. The total annual amount was 46.4 inches. At Williamstown, in the same county, but about 300 feet lower, the total annual precipitation was 46.9 inches, substantially the same as at Pittsfield. Worcester, in the same county, but 500 feet lower than Pittsfield, and 200 feet lower than Williamstown, recorded a total fall of 48.8 inches, an amount greater than either of the hill stations, while Springfield, a valley station, in the same part of the State, with an elevation of 200 feet, gave the largest precipitation of any, viz, 49.8 inches.

In New Hampshire there are three stations with elevations above 1,000 feet. The precipitation at these elevated stations was not so great as at stations much lower. The greatest measured rainfall in the State was at Nashua, Hillsboro County, elevation 125 feet. The same is true of Vermont and Maine, and what is true of a single year is true of other years.

A little reflection will show the folly of attempting to adjust rainfall observations for the supposed influence of elevation in a country of varied topography such as New England.

A final word as to the charge of "neglect of the influence of geography," on page 329, quoted by Professor Jefferson. First as to the facts: The record of heavy rainfall in the gorge of the Columbia was made at Cascade Locks, elevation about 125 feet, by the United States Engineer Corps. The course of the river at that point is nearly east and west, and there is no obstruction to the flow of the winds up and down the valley. The writer is not prepared to say that the heavy rains at Cascade Locks in the river valley are due to the presence of mountains a few miles away on either side of the river. About 35 miles farther up the valley on the east side of the Cascades the average annual rainfall is but 15.8 inches, as against 79.0 inches at Cascade Locks.

It has developed since the rainfall report was written that Glenora, Oreg., is not on the summit of the Coast Range, but has an elevation of probably 1,500 feet or less. The Coast Range in Tillamook County does not, according to the contour maps of the United States Geological Survey attain elevations above 2,000 feet except over small areas.

Additional rainfall stations have been established in Tillamook County within recent years. These all show a very heavy precipitation; thus, Bay City on the east shore of Tillamook Bay (sea level) for the four years, 1897-1900, gives an annual mean of 124 inches. Nehalem, at the mouth of the river of the same name, gives an annual mean of 115 inches (five years). The mean annual precipitation at Glenora (eight years) is 136 inches. This fact alone does not justify us in assuming a higher average precipitation for the length and breadth of the Coast Range in Oregon. What we need is more rainfall stations on the higher levels.

THE TEMPERATURE OF THE SOIL AND THE SURFACE OF THE GROUND.

By DEWEY A. SEELEY, Observer, Weather Bureau, Chicago, Ill.

The importance of soil temperature in agriculture is due both to the beneficial effects of heat in the seed bed and to the destructive effects of frosts upon growing crops. The process of germination will not begin in most cultivated crops until a temperature of 42° or more has been reached and maximum results are attained when the temperature of the soil reaches 68° or 70°. Heat is also necessary to weaken the forces which hold together the food constituents in the soil before they become available for the use of the plant. Nitrication will not take place with the soil temperature below 40°, and is most vigorous at 98°. Again, the osmotic pressure by which the plant food is taken into the plant and forced through the stem to its farthest branch and leaf, is made more effective by heat. On the other hand low temperatures, and especially frost, often cause incalculable damage to vegetation.

Purely local conditions have such a decided influence upon the temperature near the surface of the ground that the effects are apparent to the most casual observer. A heavy frost often occurs over one portion of ground while another portion in close proximity, but under different influences will be entirely free from frost. The local differences in temperature in clear weather with light winds are sufficient to be sensible to a person passing from place to place, especially over hills and valleys.

With the importance of soil temperature in view, and the influence of local conditions so apparent, a few observations were made to determine approximately the effects of some of these local conditions expressed in degrees Fahrenheit.

The first series of observations was made to determine the amount of variation in temperature due to elevation. A low swale surrounded by hills was chosen. Two minimum thermometers were placed on the bare ground, one at the lowest point in the swale and the other on the hilltop about 15 feet above. All conditions, except the elevation, were made as nearly as possible alike. The minimum temperatures, recorded on six clear, still nights in January, were as follows:

Observations.	Temperature in swale.	Temperature on hilltop.
	°	°
1	13	15
2	9.5	10.5
3	8	10.5
4	11.5	15.5
5	2	6
6	-10	-9
Average.	5.7	8.2

The average of the six readings taken on the hilltop was 2.5° higher than corresponding temperatures below. This difference is important, especially when frosts are liable to occur. In order to determine the difference between the temperature at the surface of the ground and in the free air above, another thermometer, which had been placed on a wooden frame work 30 feet high on the hilltop, was read simultaneously with the above instruments. The average of the six readings of this thermometer was 14.5°, or 6.3° higher than the average on the hilltop, and 8.8° higher than in the swale.

The effects of air drainage upon the temperature of the soil were found to be very decided. Minimum thermometers were placed on the ground; the first in a low swale without air drainage, the second on low ground at about the same elevation as the first but with very good air drainage, and the third on a hill about fifteen feet above. Readings were made on three nights with the conditions favorable for frost, and the results were as follows:

Observations.	Undrained area.	Drained area.	Hilltop.
1	25	29.5	30
2	40.5	44	44
3	30	34.5	35
Averages.	31.8	36	36.8

These averages show a difference of 4° between low ground with and without air drainage. It so happened that the average of the three readings in the low swale was slightly below the freezing point, while that of the air-drained area was amply above and nearly as high as the average on the hilltop.

A third set of readings was made to determine the effect of vegetation upon the temperature of the surface of the ground on which it was growing. Three minimum thermometers were used, the first being placed on naked soil, the second on the surface of the ground in clover about 2.5 inches high, and the third in grass 6 inches high. The table below shows the remarkable variation in temperature due to the growth of vegetation.

Observations.	Bare ground.	Clover.	Grass.
1	26	22	16
2	35	30	24
3	29.5	26	21
Averages.	30.2	26	20.8

The average temperature was over 4° lower in the clover and nearly 10° lower in the grass than on the bare ground. These differences in temperature seem incredibly large, but the observations were carefully made and all conditions surrounding the thermometers, except the covering of vegetation, were the same; hence this one element must have been the real cause of the wide variation. In cool weather live stock invariably seeks bare ground to lie down upon, and the above table shows the advantage in so doing. The bare ground absorbs more heat during the day and radiates less heat at night than does the surface covered with vegetation, and hence it is much warmer. Then, too, much more heat is used up in the process of evaporation from plants than from the naked soil. To demonstrate the fact that more water evaporates from soil on which plants are growing, three small tin cups were filled with loam. The first contained simply the soil, the second was filled with the same soil thickly covered with grass about 2 inches high, and the third the same kind of soil in which were growing 12 wheat plants about 10 inches high. Enough water was added each day for ten consecutive days to saturate the soil, the amount being measured by means of a graduated glass tube. The water evaporated from the naked soil was 43 grams; from the grass-covered soil, 72 grams; and from the soil containing wheat, 84 grams, or nearly twice the amount evaporated from the bare soil. The heat used up in evaporating this large amount of water would be sufficient to lower the temperature of the soil several degrees.

Carrying the observations further, it was found that the temperature variations were more dependent upon the height of the plants and their thickness over the surface of the ground than upon the kind of plant. One thermometer was placed in grass about 2 inches high, another in clover about the same height, and a third in grass 8 inches high. The results showed practically no differences between the readings of the first two thermometers, but the third averaged 4° lower.

Even the color of the plant was shown to have an influence upon the temperature. A frost was noticed on one portion of a lawn while another portion of the same lawn was free from it. The portion free from frost was a light-colored June grass,

while that on which the frost occurred was a very dark-colored meadow fescue. The lawn was newly mown and the grass everywhere about the same height. Apparently the only cause for one portion having frost and the other not was the color of the grass. The thermometers were carefully placed on the two plots under as nearly similar conditions as possible, and readings were taken each half hour during the night. The temperature averaged over one degree higher on the lighter colored grass. The minimum reached on the dark colored grass was 39°, while 40.5° was the lowest recorded on the light colored grass. Another thermometer was placed on a hard, gravel roadbed near by and read with the other thermometers. This averaged about 10° higher than the one in the dark grass.

The temperature at the surface of the ground is also greatly influenced by the color of the soil. Temperatures taken on dark colored muck, a lighter colored loam, and a very light clay during an afternoon in summer were, respectively, 110°, 101.5°, and 97°. Readings were also taken early the next morning, and the corresponding temperatures were 61.5°, 60°, and 63.5°.

Another important difference in temperature was observed to result from cultivation. Temperatures were taken on soil that had been newly cultivated for seeding and upon soil that had not been worked for several days. Thermometers were placed at the surface of the ground, and at 3, 6, and 12 inches below the surface. These were read at 2:30 p. m. and 2:30 a. m. the following day. The readings are given in the table below:

	Surface.		3 inches.		6 inches.		12 inches.	
	a. m.	p. m.	a. m.	p. m.	a. m.	p. m.	a. m.	p. m.
Cultivated soil	63	106	65	72	65	68	64	61
Uncultivated soil	60	102	64	77	64	68	62	60

The table shows, first, that the newly cultivated soil was 6° warmer at the surface of the ground than the uncultivated; second, that the temperature 3 inches below the surface was 5.5° higher on the uncultivated soil. These facts show that the newly cultivated soil conducts heat much more slowly than the uncultivated, probably because it is less compact. The amount of evaporation from each is probably about the same for a short time after cultivation, hence this can not be considered as a cause of the difference in temperature. When cultivation is carried on continuously, the surface of the soil is warmer, and the first few inches below the surface cooler, than upon the same soil uncultivated; while at a depth of 6 inches the cultivated soil has the same or a higher temperature than the uncultivated. These are all desirable conditions during the growing season. The warmer surface soil hastens the process of growth in the plant and is a protection against frost. The soil just below the surface being cooler, retards capillarity and thereby retains the soil moisture, while the temperature about the roots of the plant 5 or 6 inches below the surface, is the same or a little higher than on the uncultivated soil. The plan of cultivating the soil about growing crops during the afternoon of a day when the conditions are favorable for frost at night is often recommended, and the table shows that there is much to be gained by so doing. The temperature at the surface of the cultivated soil was 3° higher than on the uncultivated at 2:30 a. m., hence the danger of frost was materially lessened. The heat absorbed during the day is held near the surface of the ground in the cultivated soil, instead of being conducted to lower depths, and the air becomes more moist from the rapid evaporation at the surface, which is a condition unfavorable for the occurrence of frost.

In conclusion, the temperature at the surface of the ground has been shown to be markedly dependent upon local conditions. Many of these local conditions are under the control of man, and a better understanding of them would result in beneficial returns to the agriculturist.

THE SUN-SPOT PERIOD AND THE TEMPERATURE AND RAINFALL OF JAMAICA.

By MAXWELL HALL, Government Meteorologist, dated December 5, 1901.

At Kingston, Jamaica, the usual meteorological instruments were read from June, 1880, to the end of 1886, at 7 a. m., 3 p. m., and 11 p. m., mean local time, and the mean of the three readings was assumed to be the mean of the twenty-four hours. From January, 1887, to March, 1899, when the weather service was closed, the instruments were read at 7 a. m. and 3 p. m. only, and no means for the twenty-four hours were taken.

From the hourly readings of a very fine barograph registering almost continuously by photography, it appears that the above assumption as to the daily averages was correct as far as barometric pressure was concerned, but from the thermograph recently kept by the United States station at Halfway Tree near Kingston, it appears that the assumption was not correct for temperature.

Careful investigation shows that the average daily temperature may be determined by the use of either one of two formulæ, which we will call A and B:

$$(A) \text{ Mean temperature of the 24 hours} = \frac{M + m}{2} - 1^{\circ}, \text{ where}$$

M and m are the maximum and minimum readings, respectively;

$$(B) \text{ Mean temperature of the 24 hours} = \frac{7 \text{ a. m.} + 3 \text{ p. m.}}{2},$$

As we are unable at present to decide which is the better of the two, without hesitation we take at once—

$$\text{mean temperature of the twenty-four hours} = \frac{A + B}{2}.$$

The following table gives the means for the eighteen complete years that the service was in existence; the readings were taken by Mr. Robert Johnstone, and the errors of the instruments were checked from time to time by means of a ther-

mometer verified at Kew, England, three times during the eight years.

The thermometers were placed in a Stevenson's screen on a grass lawn about 50 feet above sea level.

Summary of Kingston mean temperatures for each year.

Year.	24 hours.	7 a. m.	3 p. m.	Max.	Min.	Highest.	Date.	Lowest.	Date.
1881	79.0	75.7	84.0	87.2	71.3	93.8	July 7	60.3	Jan. 13
1882	78.8	75.6	84.0	86.4	71.2	92.2	Aug. 27	61.5	Feb. 6
1883	79.0	75.6	84.1	86.8	71.5	93.3	July 28	63.6	Dec. 10
1884	78.5	75.3	83.8	86.3	70.7	92.7	Sept. 18	62.3	Feb. 7
1885	79.4	76.6	84.3	86.9	71.6	95.2	Nov. 6	58.2	Dec. 29
1886	79.5	76.6	84.5	89.0	70.9	96.4	Oct. 1	62.2	Jan. 26
1887	78.4	74.6	83.4	88.3	69.3	93.3	July 21	56.7	Dec. 4
1888	79.4	75.3	85.1	88.9	70.1	94.6	July 28	59.6	Jan. 5
1889	79.7	75.0	85.5	89.5	70.9	94.3	July 28	60.0	Mar. 2
1890	78.2	73.1	84.1	87.9	69.8	94.4	July 21	60.2	Feb. 4
1891	79.0	74.1	84.7	87.5	71.5	96.7	Aug. 20	61.5	Jan. 27
1892	78.1	73.6	83.4	86.7	70.7	94.8	July 11	63.0	Feb. 2
1893	77.9	73.3	83.2	86.5	70.6	92.9	July 4	63.8	* Mar. 17
1894	78.0	73.7	83.3	86.7	70.3	92.9	June 22†	61.2	Mar. 9
1895	78.6	73.7	84.3	87.5	71.0	94.6	Aug. 17	62.8	Dec. 21
1896	79.2	74.2	84.7	87.8	71.9	93.9	July 18	62.7	Jan. 15
1897	79.1	74.2	84.7	87.8	71.7	94.0	Aug. 9	62.0	Jan. 12
1898	78.2	73.3	83.6	86.9	70.7	93.5	Jan. 13	62.6	Nov. 12
Means	78.8	74.6	84.2	87.5	70.8	94.1	61.3

* And December 7. † And July 17 and September 21.

The first thing to be noticed is the break in the 7 a. m. readings. From 1881 to 1889 the mean is 75.5°; from 1890 to 1898 the mean is 73.7°. During the first nine years the screen was as well exposed as possible; during the last nine years it was exposed on the Parade Gardens, which had been recently planted with ornamental shrubs of all kinds. Of late years these shrubs have grown to be trees, and have caused anxiety as to the exposure of the screen, but it appears that the exposure was bad at first, and has not become worse with the growth of the trees. It is to be noticed, however, that the daily maximum temperatures, which occur shortly after noon, are in no way affected by the ornamental shrubs or trees. The sun is then vertical, or nearly so, and of course the screen is exposed to its full blaze. This also applies to the 3 p. m. readings. Again, the minimum readings have not been affected. It is therefore to be hoped that the mean temperatures, as computed by the formula $\frac{A + B}{2}$, are not greatly

in error. But when we look down the maximum column we are surprised to find that the two lowest results occur in 1884

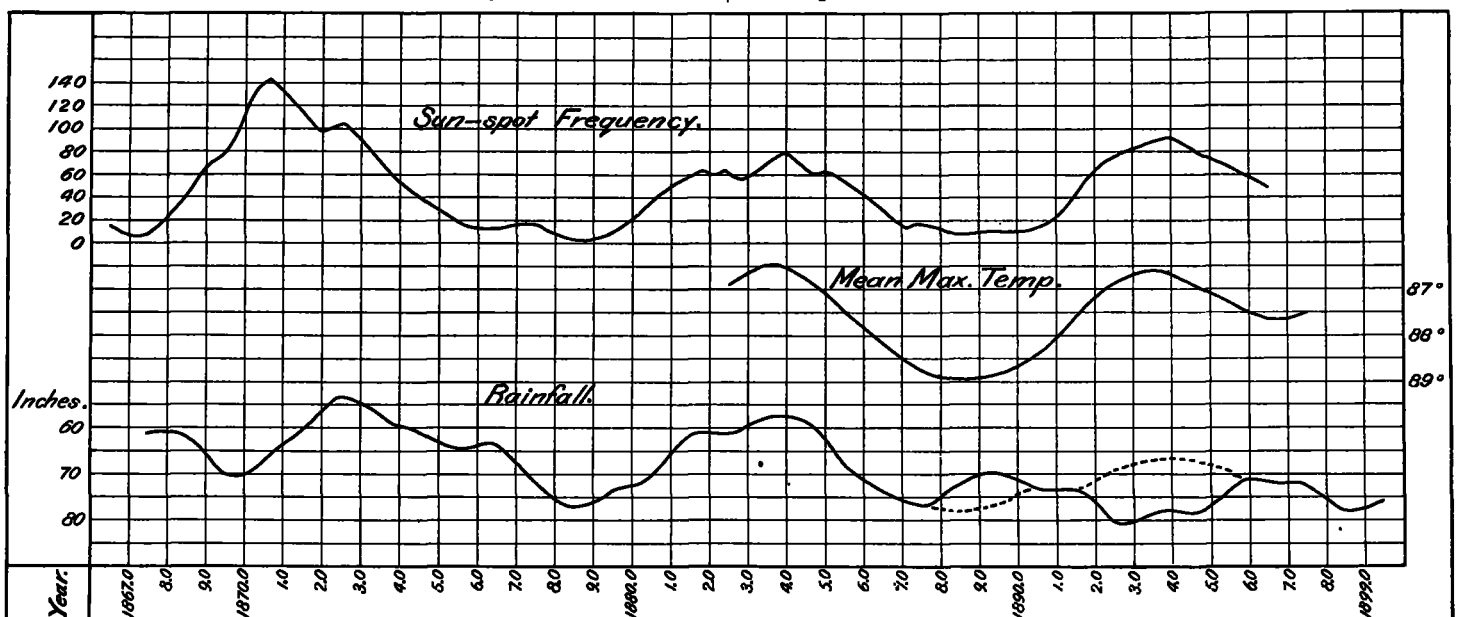


FIG. 1.—Sun spots, temperature, and rainfall for Jamaica.